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(54) Title: PHARMACEUTICAL COMPOSITIONS CONTAINING DRUGS WHICH ARE INSTABLE OR SPARINGLY SOLUBLE IN WATER AND METHODS FOR THEIR PREPARATION (57) Abstract Novel pharmaceutical compositions comprise inclusion compounds of drugs, which are instable or only sparingly soluble in water, with partially etherified β -cyclodextrin derivatives having hydroxyalkyl and optionally additional alkyl groups.		

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5 Pharmaceutical compositions containing drugs which
 are instable or sparingly soluble in water
 and methods for their preparation

10 The invention relates to pharmaceutical compositions containing drugs which are instable or only sparingly soluble in water, and methods for their preparation. The compositions are characterized by increased water solubility and improved stability.

15 A large number of drugs is only poorly or sparingly soluble in water so that suitable application forms like drop solutions or injection solutions are being prepared using other polar additives like propylene glycol etc. If
20 the drug molecule has basic or acidic groups there exists the further possibility of increasing the water solubility by salt formation. As a rule this results in decreased efficacy or impaired chemical stability. Due to the shifted distribution equilibrium the drug may penetrate the lipophilic membrane only slowly corresponding to the
25 concentration of the non-dissociated fraction while the ionic fraction may be subject to a rapid hydrolytic decomposition.

30 Additional "water-like" solvents like low molecular polyethylene glycols or 1,2-propylene glycol are therefore used in the preparation of aqueous solutions of sparingly water-soluble drugs which glycols, however, cannot be considered pharmacologically inert, or the drug is solubilized using surfactants so that the drug molecules are
35 occluded in micells. This solubilization has numerous

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disadvantages: The surfactant molecules used have frequently a strongly haemolytic effect and the drug needs to pass out of the micell by diffusion after the application. This results in a retard effect (compare B.W. Müller, Gelbe Reihe, Vol. X, pages 132ff (1983)).

Accordingly it may be stated that there exists no satisfactory and generally applicable method of solubilization.

For solid drugs it is also important to render the sparingly water-soluble drug water-soluble since a good solubility increases the bioavailability of the drug. It has been described that inclusion compounds, e.g. with urea or complexes of polyvinyl pyrrolidone may improve the solubility of a compound but in aqueous solution they are not stable. Such inclusion compounds are therefore at best suitable for solid application forms of drugs.

This is different when using α -, β -, and γ -cyclodextrin which can bind a drug in its ring also in aqueous solution (W. Sängler, Angewandte Chemie 92, 343 (1980)). However, it is disadvantageous that the β -cyclodextrin itself is only poorly water-soluble (1.8 g/100 ml) so that the therapeutically necessary drug concentrations are not achieved.

If a derivative is formed of the cyclodextrin its solubility and therefore the amount of dissolved drug may be considerably increased. Thus, German Offenlegungsschrift 31 18 218 discloses a solubilization method using methylated β -cyclodextrin as monomethyl derivative with 7 methyl groups and especially as dimethyl derivative with 14 methyl groups. With the 2,6-di-O-methyl derivative it is for instance possible to increase the water solubility of indometacin 20.4-fold and that of digitoxin 81.6-fold.

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However, for therapeutical use the methyl derivatives of β -cyclodextrin show serious draw backs. Due to their increased lipophility they have a haemolytic effect and they further cause irritations of the mucosa and eyes. Their acute intravenous toxicity is still higher than the already considerable toxicity of the unsubstituted β -cyclodextrin. It is a further serious disadvantage for the practical application that the solubility of the dimethyl β -cyclodextrin and its complexes suffers a steep decrease at higher temperatures so that crystalline dextrin precipitates upon heating. This phenomenon makes it very difficult to sterilize the solutions at the usual temperatures of 100 to 121°C.

Quite surprisingly it has now been found that certain other β -cyclodextrin derivatives can form inclusion compounds which also considerably increase the water-solubility of sparingly water-soluble and instable drugs without showing the advantages described above.

Subject of the invention are therefore novel pharmaceutical compositions comprising inclusion compounds of only sparingly water-soluble and in water instable drugs with a partially etherified β -cyclodextrin of the formula

(β -CD)OR (I),

in which the residues R are hydroxyalkyl groups and part of the residues R may optionally be alkyl groups, the β -cyclodextrin ether having a water-solubility of more than 1.8 g in 100 ml water.

A partially etherified β -cyclodextrin of formula I is preferably used in which the residues R are hydroxyethyl, hydroxypropyl or dihydroxypropyl groups. Optionally part of the residues R may for instance be methyl or ethyl

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groups; the use of partially methylated β -cyclodextrin ethers with 7 to 14 methyl groups in the β -cyclodextrin molecule, as they are known from German Offenlegungsschrift 31 18 218 do not come under the present invention.

5 Partial ethers of β -cyclodextrin comprising only alkyl groups (methyl, ethyl) may be suitable in accordance with the invention if they have a low degree of substitution (as defined below) of 0.05 to 0.2.

10 β -cyclodextrin is a compound with ring structure consisting of 7 anhydro glucose units; it is also referred to as cycloheptaamylose. Each of the 7 glucose rings contains in 2-, 3-, and 6-position three hydroxy groups which may be etherified. In the partially etherified β -cyclodextrin
15 derivatives used according to the invention only part of these hydroxy groups is etherified with hydroxyalkyl groups and optionally further with alkyl groups. When etherifying with hydroxy alkyl groups which can be carried out by reaction with the corresponding alkylene oxides,
20 the degree of substitution is stated as molar substitution (MS), viz. in mole alkylene oxide per anhydroglucose unit, compare US patent specification 34 59 731, column 4. In the hydroxyalkyl ethers of β -cyclodextrin used in accordance with the invention the molar substitution is between
25 0.05 and 10, preferably between 0.2 and 2. Particularly preferred is a molar substitution of about 0.25 to about 1.

The etherification with alkyl groups may be stated directly as degree of substitution (DS) per glucose unit which -
30 as stated above - is 3 for complete substitution. Partially etherified β -cyclodextrins are used within the invention which comprise besides hydroxyalkyl groups also alkyl groups, especially methyl or ethyl groups, up to a
35 degree of substitution of 0.05 to 2.0, preferably 0.2 to 1.5. Most preferably the degree of substitution with alkyl groups is between about 0.5 and about 1.2.

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The molar ratio of drug to β -cyclodextrin ether is preferably about 1:6 to 4:1, especially about 1:2 to 1:1. As a rule it is preferred to use the complex forming agent in a molar excess.

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Useful complex forming agents are especially the hydroxyethyl, hydroxypropyl and dihydroxypropyl ether, their corresponding mixed ethers, and further mixed ethers with methyl or ethyl groups, such as methyl-hydroxyethyl, methyl-hydroxypropyl, ethyl-hydroxyethyl and ethyl-hydroxypropyl ether of β -cyclodextrin.

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The preparation of the hydroxyalkyl ethers of β -cyclodextrin may be carried out using the method of US patent specification 34 59 731. Suitable preparation methods for β -cyclodextrin ethers may further be found in J. Szejtli et al., Stärke 32, 165 (1980) und A.P. Croft and R.A. Bartsch, Tetrahedron 39, 1417 (1983). Mixed ethers of β -cyclodextrin can be prepared by reacting β -cyclodextrin in a basic liquid reaction medium comprising an alkali metal hydroxide, water and optionally at least one organic solvent (e.g. dimethoxyethane or isopropanol) with at least two different hydroxyalkylating and optionally alkylating etherifying agents (e.g. ethylene oxide, propylene oxide, methyl or ethyl chloride).

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Drugs exhibiting a significantly increased water-solubility and improved stability, respectively, after having been transferred into inclusion compounds with the above-mentioned β -cyclodextrin ethers are those having the required shape and size, i.e. which fit into the cavity of the β -cyclodextrin ring system. This includes for instance non-steroid anti-rheumatic agents, steroids, cardiac glycosides and derivatives of benzodiazepine, benzimidazole, piperidine, piperazine, imidazole or triazole.

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Useful benzimidazole derivatives are thiabendazole, fuberidazole, oxibendazole, parabendazole, cambendazole, mebendazole, fenbendazole, flubendazole, albendazole, oxfendazole, nocodazole and astemisole. Suitable piperadine derivatives are fluspirilene, pimozide, penfluridole, loperamide, astemizole, ketanserine, levocabastine, cispripide, altanserine, and ritanserine. Suitable piperazine derivatives include lidoflazine, flunarizine, mianserine, oxatomide, mioflazine and cinnarizine. Examples of suitable imidazole derivatives are metronidazole, ornidazole, ipronidazole, tinidazole, isoconazole, nimorazole, burimamide, metiamide, metomidate, enilconazole, etomidate, econazole, clotrimazole, carnidazole, cimetidine, docodazole, sulconazole, parconazole, orconazole, butoconazole, triadiminole, tioconazole, valconazole, fluotrimazole, ketoconazole, oxiconazole, lombazole, bifonazole, oxmetidine, fenticonazole and tubulazole. As suitable triazole derivatives there may be mentioned virazole, itraconazole and terconazole.

Particularly valuable pharmaceutical compositions are obtained when converting etomidate, ketoconazole, tubulazole, itraconazole, levocabastine or flunarizine into a water-soluble form using the complex forming agents of the invention. Such compositions are therefore a special subject of the present invention.

The invention is further directed to a method of preparing pharmaceutical compositions of sparingly water-soluble or water-instable drugs which is characterized by dissolving the β -cyclodextrin ether in water and adding thereto the selected drug as well as optionally drying the solution of the formed inclusion compound using methods known per se. Formation of the solution may take place at temperatures between 15 and 35°C.

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5 The drug is suitably added batchwise. The water may further comprise physiologically compatible compounds such as sodium chloride, potassium nitrate, glucose, mannitole, sorbitol, xylitol or buffers such as phosphate, acetate or citrate buffer.

10 Using β -cyclodextrin ethers in accordance with the invention it is possible to prepare application forms of drugs for oral, parenteral or topical application, e.g. infusion and injection solutions, drop solutions (e.g. eye drops or nasal drops), sprays, aerosols, sirups, and medical baths.

15 The aqueous solutions may further comprise suitable physiologically compatible preserving agents such as quarternary ammonium soaps or chlorbutanol.

20 For the preparation of solid formulations the solutions of the inclusion compounds are dried using conventional methods; thus the water may be evaporated in a rotation evaporator or by lyophilisation. The residue is pulverized and, optionally after addition of further inert ingredients, converted into uncoated or coated tablets, suppositories, capsules, creams or ointments.

25 The following examples serve to illustrate the invention which, however, is not restricted to the examples.

30 The phosphate buffer solution mentioned in the examples had a pH of 6.6 and the following composition:

KH_2PO_4	68,05 g
NaOH	7,12 g
Aqua demin. ad.	5000,0 g

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All percentages are percent by weight.

Example 1

5 Starting from a 7% master solution of hydroxyethyl β -cyclo-
dextrin (MS 0.43) in phosphate buffer solution a dilution
series was prepared so that the complex forming agent
concentration was increased in steps of 1%. 3 ml of these
10 solutions were pipetted into 5 ml snap-top-glasses contain-
ing the drug to be tested. After shaking for 24 hours at
25°C the solution was filtered through a membrane filter
(0.22 microns) and the dissolved drug content was determin-
ed spectrophotometrically. Figures 1, 3 and 4 show the
15 increase of the drug concentration in solution in relation
to the concentration of the complex forming agent for
indometacin (figure 1), piroxicam (figure 3) and diazepam
(figure 4). The maximum drug concentration is limited by
the saturation solubility of the cyclodextrin derivative
20 in the buffer which in case of hydroxyethyl- β -cyclodextrin
(MS 0.43) is reached at 7.2 g/100 ml.

When comparing for instance the results obtained with
indometacin to those given in German Offenlegungsschrift
31 18 218 for 2,6-di-O-methyl- β -cyclodextrin (figure 2) it
25 will be observed that the hydroxyethyl derivative has a
significantly higher complex formation constant (compare
the different slopes in figures 1 and 2).

Example 2

30 A. The saturation solubility at 25°C of different
drugs was determined using a 10% hydroxypro-
pyl- β -cyclodextrin solution (MS 0.35) in
phosphate buffer solution under the same
conditions as in example 1. The saturation
35 solubilities S_1 in phosphate buffer solution and

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S_2 in phosphate buffer solution and 10% added hydroxypropyl- β -cyclodextrin are given in table 1.

5 Table 1

Drugs	S_1 (mg/ml)	S_2 (mg/ml)	Ratio $S_1:S_2$
Indometacine	0,19	5,72	1: 30,1
10 Digitoxine	0,002	1,685	1: 842,5
Progesterone	0,0071	7,69	1: 1083,0
Dexamethasone	0,083	14,28	1: 172,0
Hydrocortisone	0,36	21,58	1: 59,9
15 Diazepam	0,032	0,94	1: 29,4

15 B. The solubility of drugs in a 4% aqueous solution of hydroxypropyl-methyl- β -cyclodextrin (DS 0.96; MS 0.43) was determined in a similar manner. The results obtained are summarized in the following

20 table 2 in which the ratio R of the saturation solubility in water or at the stated pH, respectively, with an without addition of β -cyclodextrin derivative is stated for each drug. The solutions prepared according to the invention

25 were further found to be significantly more stable when compared with aqueous solutions.

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Table 2

	<u>Drug</u>			<u>R</u>
5	Itraconazole	at	pH 5	96
		at	pH 2,5	75
	Flunarizine			18
	Levocabastine	at	pH 9,5	81
		at	pH 7,4	8
10	Ketoconazole			85
	Flubendazole			30
	Tubulazole			43
	Cisapride			3
	Loperamide			62
15	Etomidate			8,5
	Cinnarizine	at	pH 5	28
		at	pH 3	12

Example 3

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In 10 ml phosphate buffer solution 0.7 g hydroxyethyl- β -cyclodextrin (MS 0.43) were dissolved together with 0.04 g indometacin at 25°C until a clear solution was formed. This solution was filtered through a membrane filter (0.22 microns) and filled under laminar flow into a pre-sterilized injection bottle which was stored at 21°C (B). In a parallel test a saturated indometacin solution in a phosphate buffer solution (0.21 mg/ml) was stored under the same conditions (A). The drug concentrations determined by high pressure liquid chromatography are given in table 3. The great improved stability of the composition according to the invention is apparent.

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Table 3

	Storing time in weeks	Indometacin content (%)	
		A	B
5	0	100,1	99,7
	2	91,2	99,9
	4	79,1	98,1
	6	69,8	98,6
10	8	64,8	98,4

Example 4 (Injectable formulation)

15 0.35 g hydroxypropyl- β -cyclodextrin (MS 0.35) were dissolved in 5 ml of physiological sodium chloride solution and warmed to about 35°C whereafter 3 mg diazepam were added. After storing for a short time a clear solution was obtained which was filled into an ampule after filtration
20 through a membrane filter (0.45 microns).

Example 5 (Tablet)

25 In 100 ml water 7 g hydroxyethyl- β -cyclodextrin (MS 0.43) and 0.5 g medroxyprogesterone acetate were dissolved. The water was then evaporated in a rotation evaporator. The residue (75 mg) was powdered and after addition of 366 mg calcium hydrogen phosphate.2H₂O, 60 mg corn starch, 120 mg cellulose powder (microcrystalline), 4.2 mg highly dispersed silica (AEROSIL^R 200) and 4.8 mg magnesium stearate
30 tablets with a weight of 630.0 mg and comprising 5 mg drug per unit dose were made. The dissolution rate of the medroxyprogesterone acetate from this formulation is 21 times higher when compared to a tablet comprising the same
35 inert ingredients without addition of the β -cyclodextrin ether.

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Example 6

5 g hydroxyethyl- β -cyclodextrin (MS 0,43) and 14 mg vitamin A-acetate were dissolved with stirring in 100 ml water or sugar solution (5% aqueous solution) within 2.5 hours under a nitrogen atmosphere. After filtration through a membrane filter (0.45 microns) the solution was filled into ampules and sterilized or filled into dropper bottles with addition of 0.4% chlor butanol as preserving agent.

Example 7

5 or 7.5 g hydroxyethyl β -cyclodextrin (MS 0.43) and 0.5 or 0.75 g Lidocaine were dissolved in 100 ml of physiological sodium chloride solution at 30°C (B). Injection solutions, eye droplets and solutions for topical use were prepared therefrom as described in example 6. When comparing the anaesthetic effect of these solutions in animal tests with an aqueous lidocain HCl solution (A) one observes an extension of the duration of the effect by 300%. Test: rats, injection of 0.1 ml into the tail root in the vicinity of the right or left nerve fillaments and electrical irritation. The test results are summarized in table 4.

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Table 4

5	Drug concentration (%)	Duration of effect (min)		Extension (%)
		A	B	
	0,5	56	163	291
	0,75	118	390	330

Example 8

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6 mg dexamethasone and 100 mg hydroxyethyl- β -cyclodextrin (MS 0.43) were dissolved in 5 ml water, sterilized by filtration through a membrane filter (0.22 microns) and packed into an aerosol container allowing to dispense 0.1 ml per dose.

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Example 9

The acute intravenous toxicity of some β -cyclodextrins was tested on rats with the following results. It was surprisingly found that the toxicity of the derivatives used according to the invention is lower by an entire order of magnitude.

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Table 5LD₅₀ in rats (i.v.) in mg/kg bodyweight

5		
	β-cyclodextrin	453
	dimethyl-β-cyclodextrin (DS 2.0)	200-207
	hydroxypropyl-methyl-	
10	β-cyclodextrin (DS 0.96; MS 0.43)	> 2000*

* a higher dose has not been tested. In mice the value was
 > 4000 mg/kg.

15

The haemolytic effect of the methylether according to
 German Offenlegungsschrift 31 18 218 was compared to that
 of an ether used according to the invention. To this end
 100 µl of a physiological sodium chloride solution with a
 20 cyclodextrin content of 10%, 800 µl of a buffer (400 mg
 MOPS, 36 mg Na₂HPO₄ · 2 H₂O, 1,6 g NaCl in 200 ml H₂O) and
 100 µl of a suspension of human red blood cells (three
 times washed with sodium chloride solution) were mixed for
 30 minutes at 37°C. Thereafter the mixture was centrifuged
 25 and the optical density was determined at 540 nm.

Controls:

- a) 100 µl sodium chloride solution + buffer → 0% haemo-
 lysis
 30 b) 900 µl water → 100% haemolysis

The results obtained are summarized in the following table
 6 in which the concentrations are stated at which 50% and
 100% haemolysis occurred.

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Table 6

Substance	C ₅₀ %	C ₁₀₀ %
5		
Dimethyl-β-CD (DS 2.0)	0,33%	0,5%
Methyl-β-CD (DS 1.79)	0,53	0,8%
10 Hydroxypropyl- methyl-β-CD (DS 0.96; MS 0.43%)	1,5%	4 %

15 The results show that the haemolytic effect of the hydroxypropylmethyl ether is about 5 to 8 times weaker than that of the dimethyl ether according to the prior art. Animal tests have further shown that the hydroxyalkyl ethers do not cause irritation of the mucosa and eyes in contrast to the methyl ethers.

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WE CLAIM:

1. Pharmaceutical composition comprising an inclusion
compound of drugs which are instable or only sparingly soluble
5 in water with a partially etherified β -cyclodextrin of the
formula



10 in which the residues R are hydroxyalkyl groups and in which
part of the residues R may optionally be alkyl groups, the
 β -cyclodextrin ether having a water solubility of more than
1.8 g in 100 ml water.

15 2. Composition according to claim 1, characterized in
that it comprises a partially etherified β -cyclodextrin of
formula I, in which the residues R are hydroxyethyl, hydroxy-
propyl or dihydroxypropyl groups and in which part of the
residues R may optionally be methyl or ethyl groups.

20 3. Composition according to claims 1 or 2, characterized
in that they comprise a partially etherified β -cyclodextrin of
formula I with a molar substitution by hydroxyalkyl groups of
0.05 to 10 and a degree of substitution by alkyl groups of
25 0.05 to 2.0.

30 4. Composition according to anyone of the claims 1 to 3,
characterized in that it comprises the drug and the β -cyclo-
dextrin ether in a molar ratio of 1:6 to 4:1.

35 5. Composition according to anyone of claims 1 to 4,
characterized in that it comprises as drug a non-steriod
anti-rheumatic agent, a steroid, a cardiac glycoside or
derivatives of benzodiazepine, benzimidazole, piperidine,
piperazine, imidazole or triazole.

6. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug etomidate.

5 7. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug ketoconazole.

8. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug itraconazole.

10 9. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug levocabastine.

10. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug flunarizine.

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11. Composition according to anyone of claims 1 to 5, characterized in that it comprises as drug tubulazole.

20 12. A method of preparing a pharmaceutical composition according to anyone of claims 1 to 11, characterized in that the β -cyclodextrin ether is dissolved in water and that the selected drug is added whereafter the solution of the inclusion compound thus obtained is optionally dried using methods known per se.

25

13. The method of claim 12, characterized in that the residue obtained after removal of the solvent is pulverized and, optionally after addition of further inert ingredients, transferred into a solid application form.

30

14. The method of claims 12 or 13, characterized in that further physiologically acceptable substances are added to the water.

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15. The method of claim 14 , characterized in that sodium chloride, glucose, mannitol, sorbitol, xylitol or a phosphate or citrate buffer are added to the water.

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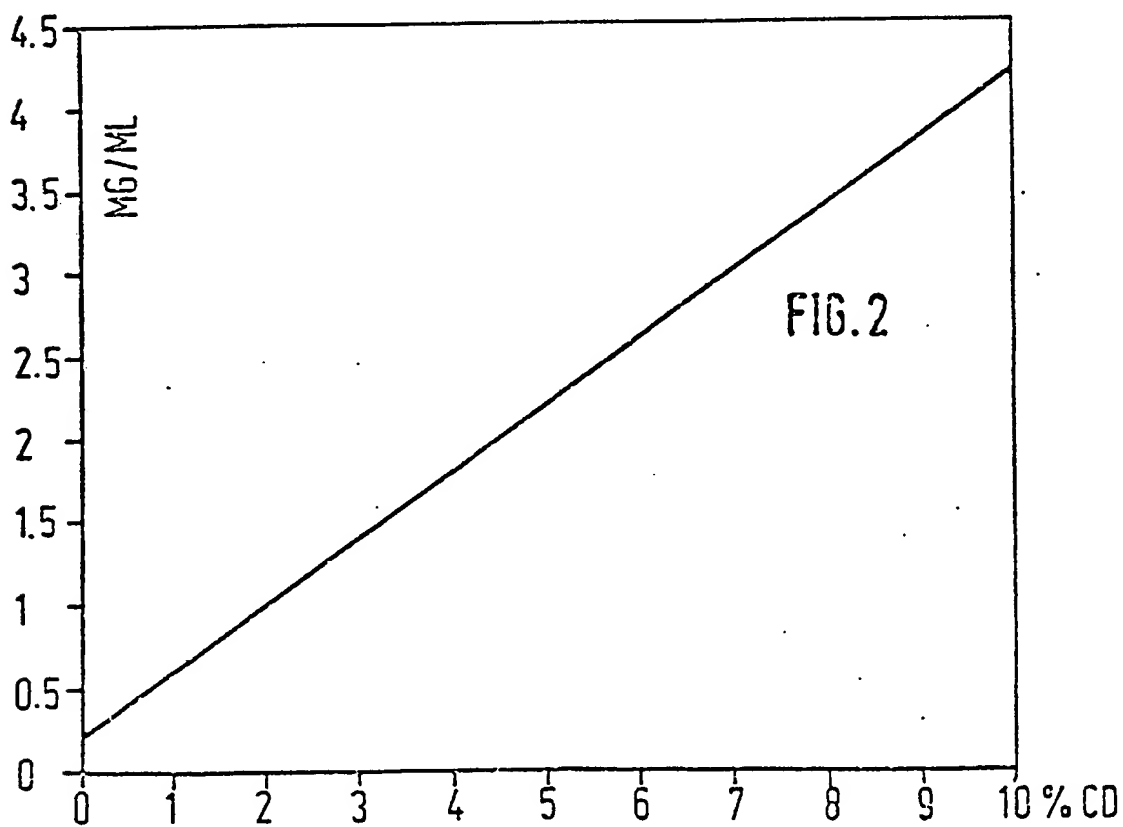
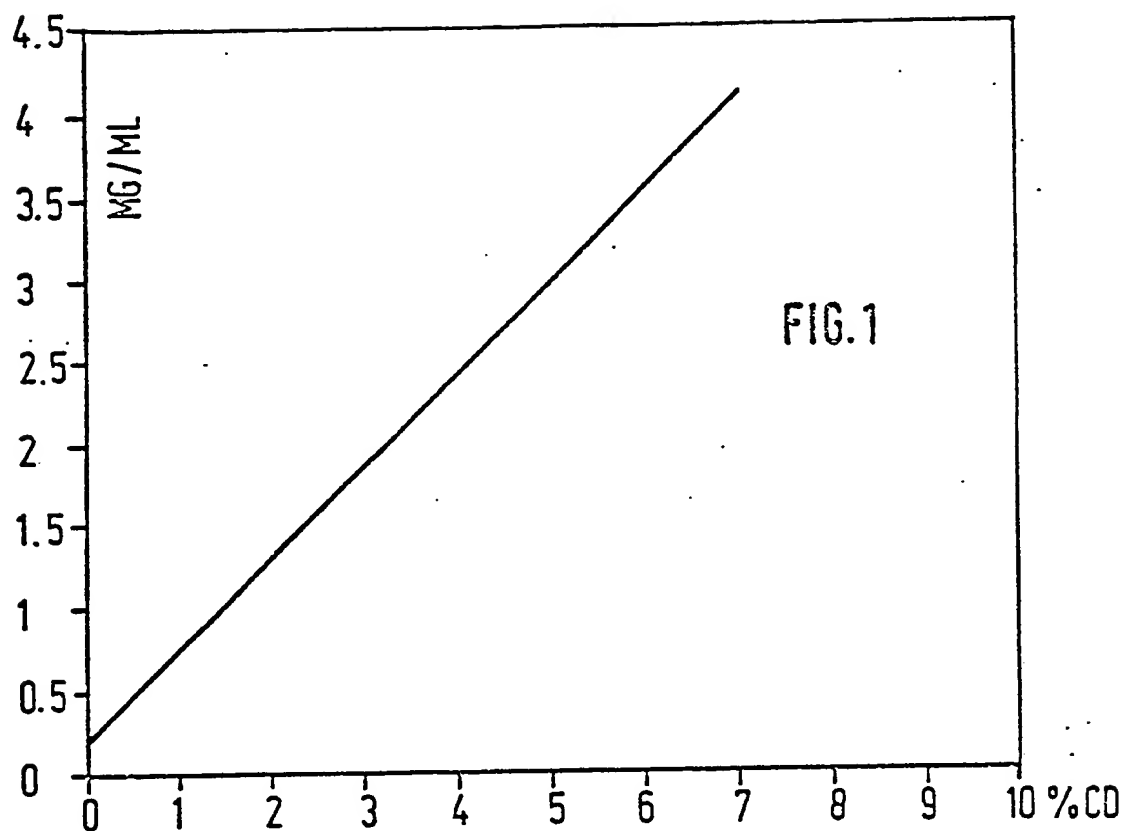
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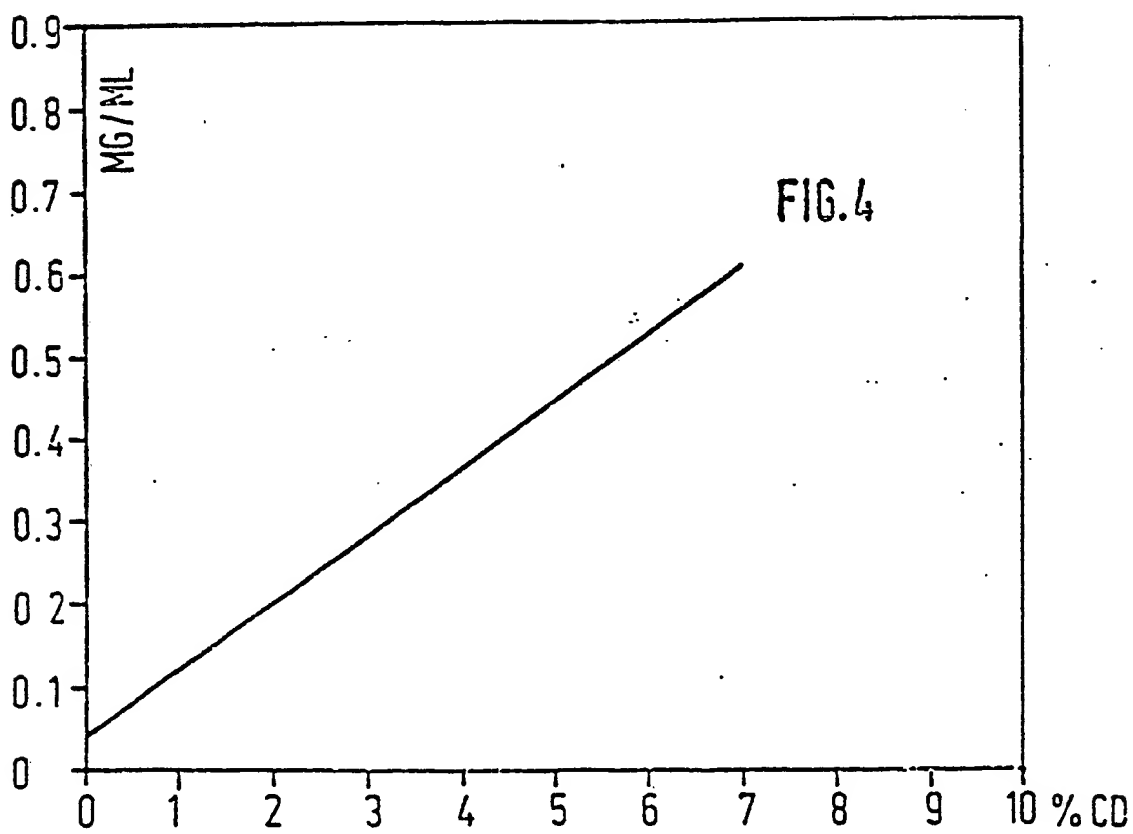
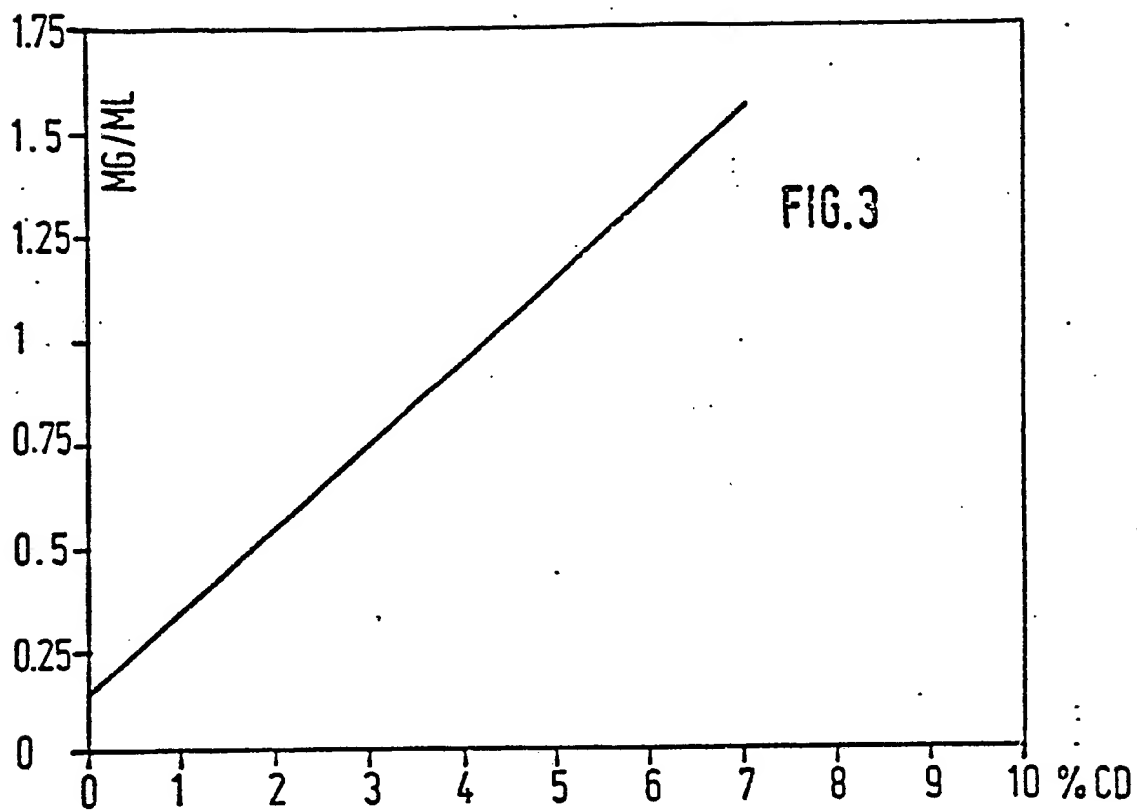
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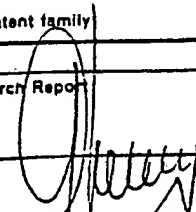




INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 84/00417

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁴		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ⁴ : A 61 K 9/18; C 08 B 37/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁴	A 61 K; C 08 B; C 08 L	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X,Y	WO, A, 82/00251 (SECRETARY U.S. DEPARTMENT OF COMMERCE USA) 4 February 1982, see page 1, lines 5-17; page 10, lines 1-33; claims 2-4,8-11,21-27 --	1-5
Y	US, A, 3453259 (S.M. PARMETER et al.) 1 July 1969, see column 1, line 1 - column 4, line 52; column 5, examples I, II; column 6, lines 26-31; claims 1,2,5,8,9 --	1-15
Y	FR, A, 1548917 (CORN PRODUCTS COMPANY) 28 October 1968, see page 5, column 1, lines 25-44; abstract A, points 1-8,10, 11 & US, A, 3459731 (cited in the application) --	1-15
Y	FR, A, 2484252 (CHINOIN GYOGYSZER-ES-VEGYESZETI TERMEKEK GYARA RT) 18 December 1981, see claims 1-8,23-34 & DE, A, 3118218 (cited in the application) -----	1-15
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Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
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